# OTDM BASED PASSIVE OPTICAL NETWORKS

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**Abstract**: In this paper we describe Passive Optical Networks (PONs) and propose solution for increasing available distance and bandwidth of PONs. In this ages the bandwidth limit of PONs is about 40 Gbps. Using of Optical Time Domain Multiplexing (OTDM) with the clock signal can be way for high speed PON in next future.

**Keywords**: PON, OTDM, acces network

## 1 INTRODUCTION

In addition of a new Internet services like Triple Play and increasing user demands grow the requirement for greater bandwidth. Internet traffic grows around 50-70% per year.[1] Copper wiring are close to their limits - both achievable distance and bandwidth, and optical fiber seems to be the best appropriate solution. Gradually, optical fibers spread from a core networks to acces networks.[2]

Data transport in optical networks can be presented by Time Division Multiplexing (TDM) and Wavelenght Division Multiplexing (WDM), where TDM can be realize electricaly (ETDM) or opticaly (OTDM).

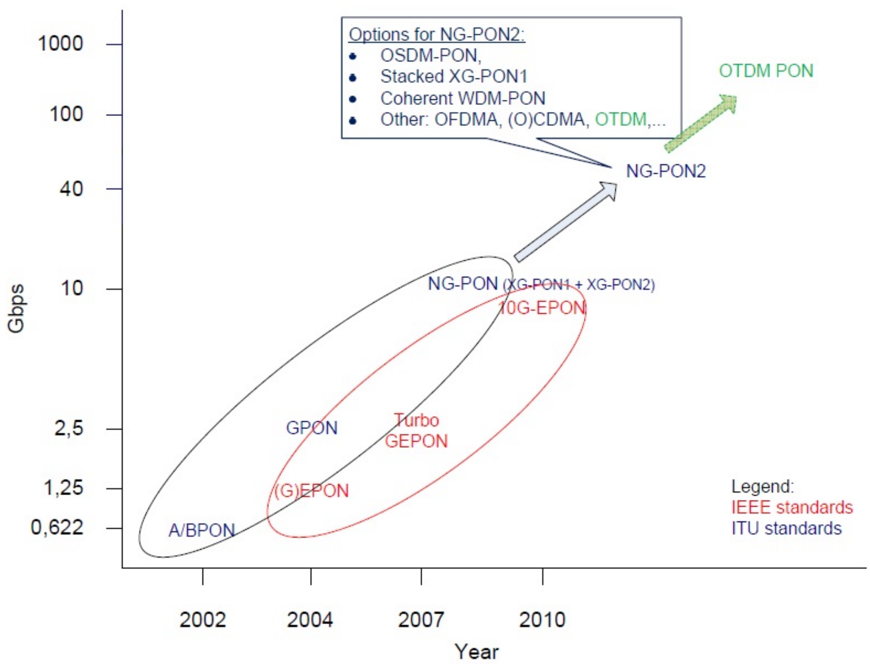


**Figure 1:** PON standards and options for future standards.

New trends in optical acces networks are Point To Multipoint (P2MP) Passive Optical Networks (PONs), which are more economical than Active Optical Networks (AONs). Distribution of data signal is made by passive equipments like Optical Splitter (OS) or Arrayed Waveguide Grating (AWG). Using of passive components means cost reductions for servicing and maintenance. Disadvantages of these PONs are lower achievable distance and lower bandwidth compared with AON.[2] Comparation of PON standards is shown in fig. 1. As you can see, actual maximal bandwidth is 10 Gbps for TDMA networks and WDM networks. Combination WDM-TDM is possible way for increaseing bandwith. When evolving from standard NG-PON1 to NG-PON2, more technologies are available for long-term evolution. Therefore, upgrades with more intense innovations can be envisioned - possible methods are [3]: 40G, WDM PON, OFDM-PON (Orthogonal Frequency Division Multiplexing PON), ODSM-PON (Opportunistic and Dynamic Spectrum Management PON), CDMA-PON (Code Division Multiple Access PON), etc.

Another bandwidth increasing of PONs can be realized by OTDM, which has no electronics limitations and so can be used for high-speed data generation. This method can be discused as one of the NG-PON2 method or rather as method for next standard after NG-PON2 because of OTDM transmittion possibilities (actually the research groups achieved over 10.2 Tbps per one channel).

## 2 OTDM SIMULATION AND BASIC OTDM PON DESIGN

In this chapter we simulate the error free OTDM network with bandwidth of 160 Gbps. Simulation was done with OptSim software from RSoft Design Group.[4] The basic OTDM PON designs are shown in next subsection.

### 2.1 160 Gbps OTDM simulation

For better understanding of OTDM this subsection demonstrate transmission of 160 Gbps and demultiplexing in OTDM network. Scheme in fig. 2 is devided in 4 main parts - transmitter, control signal, Symmetrical Mach-Zehnder Interferometer (SMZ) and receiver.

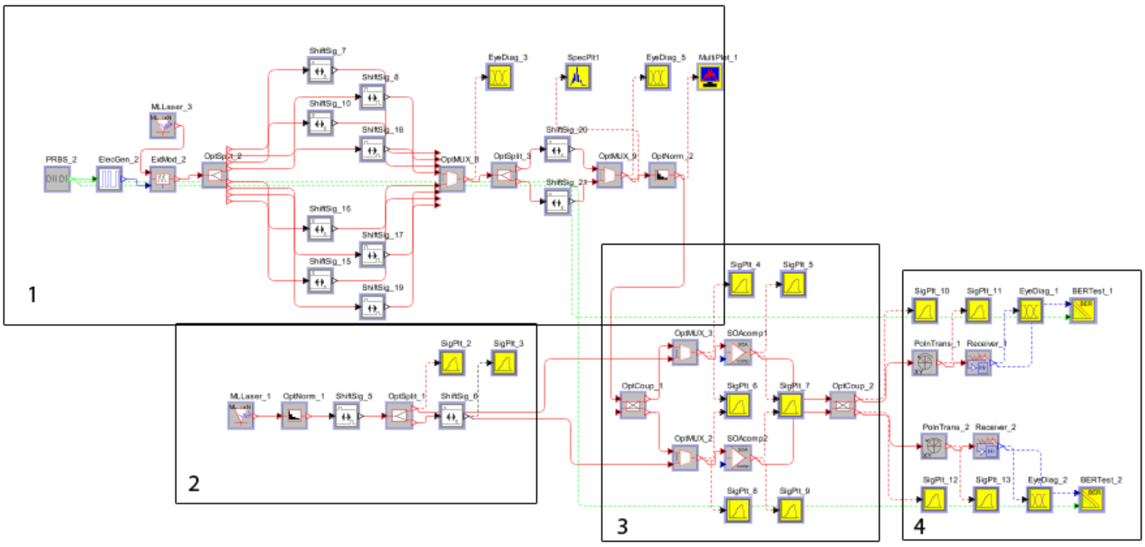

**Figure 2:** Scheme of 160 Gbps OTDM network.

Transmitter part (part 1 in fig. 2) in this simulation is based on generating 16x10 Gbps. Eight channels on the same wavelenght 1550 nm and with different pseudo random bit sequence (PRBS) are modulated by NRZ modulation. After modulation every chanel is delayed by 1/8 time window and multiplexed. Output is multiplexed again with delayed by 1/2 time and total power is set to -12 dBm. Transmitted 160 Gbps signal and its spectrum are shown in fig. 4

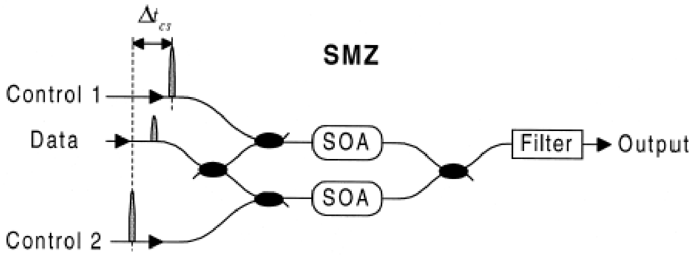


**Figure 3:** TOAD based on Symmetrical Mach-Zehnder Interferometer.[4]

The important part of the Symmetrical Mach-Zehnder Interferometer (part 3 in fig. 2) is 10 GHz control signal (part 2 in fig. 2). Control signal is used for switching when it saturates the Semiconductor optical amplifier (SOA) in the loop and changes the index of refraction. Between two counterpropagating data pulses the differential phase shift is achieved for data pulses switching to the output port. SOA offset from center position then provide a switching window duration. Principle of the Teraherz Optical Asymetric Demultiplexer (TOAD) based on SMZ is shown in fig. 3.

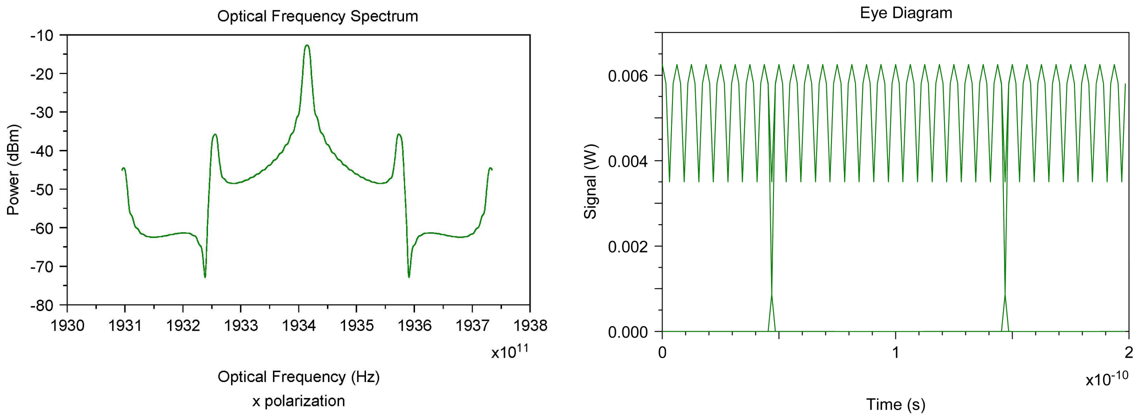


**Figure 4:** Left: Frequency spectrum of the 160 Gbps OTDM signal., Right: OTDM signal in time domain.

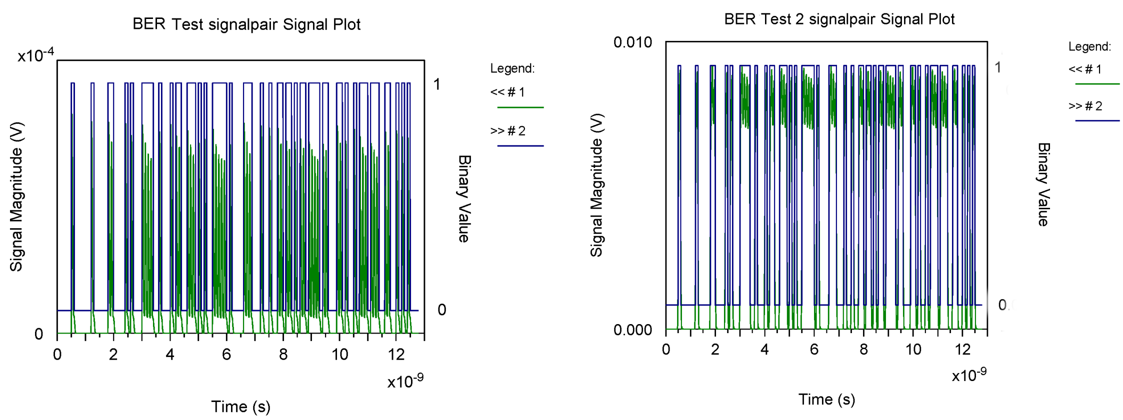


**Figure 5:** Left: Detail of output pulses from switching port with bit pattern for channel 1., Right: Detail of output pulses from reflective port with bit pattern for channel 1.

The signal from SMZ is further fed to the receiver part (part 4 in fig. 2) where polarization filter is used for data signal and clock signal dividing. Detail of signals aligned with bit pattern from switching and reflective ports of demultiplexed channel are shown in fig. 5.

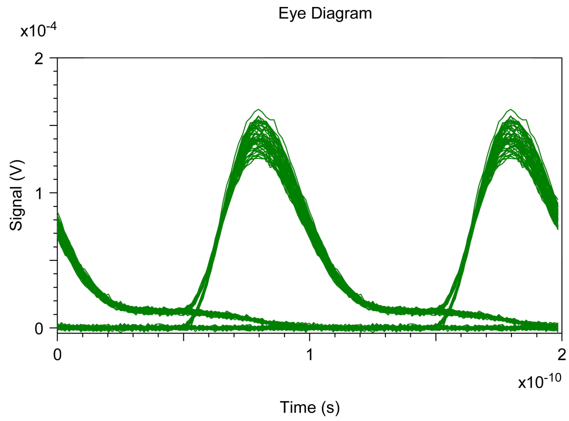


**Figure 6:** Eye diagram for output from switching port.

Output signal at switching port carries data information of demultiplexed channel and suppressed interference from other channels. Figure 6 shows corresponding eye diagram of switching port at receiver part.

## 2.2 OTDM PON DESIGNS

There are three basic possible options for passive optical networks based on OTDM signal transmission.

In the first type transmitted signal is split into 1:N by optical splitter and each output branch of PON will demultiplex all OTDM channels. After demultiplexing, each optical network unit (ONU) takes its own data and drop data of other units. Disadvantage of this design option is demultiplexing all OTDM channels in each output branch and also lower security because of channels sharing.

Next type is similar like first type, but each branch of split network demultiplex only its own OTDM channels. This is possible with marking of the first OTDM channel that can be done e.g. by space between each OTDM signal blocks, special clock signal with the same timing as first OTDM signal on another wavelenght, etc.

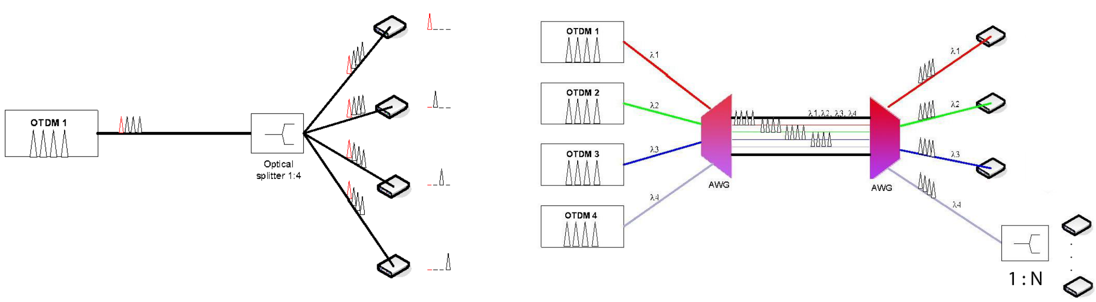


**Figure 7:** Left: OTDM PON with signal marking., Right: OTDM/WDM PON.

Last type of OTDM PON is based on WDM/OTDM combination where multiple OTDM sources are used. Each OTDM signal is transmitted separately over optical fiber on diferent wavelenght and then is each OTDM signal split by AWG. Because of the low attenuation of AWG and using a separate wavelenghts, this type of OTDM PON is the best options for long distances, better security and the highest bandwidth.

## 3 CONCLUSION

We have suggested the possibility of using OTDM signal in passive optical networks. Actual transmission limits in OTDM networks are about Tbps over more than 100 km. Output from simulation shows very good results of transmission of OTDM signal in optical networks. With the knowledge of the principle of spreading OTDM signal we have proposed three types of OTDM/PONs. These massive PONs find application rather in Fiber to the buiding PON to connect university or government buildings with a single shared fiber.

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